

ed

ity revised

Reprint

Supersedes

Date received

1/9/73

MRR-970  
Reg. 320-73  
51-T-14-73

# EVALUATION OF PAPER, COTTON, AND POLYETHYLENE-FILM BAGS FOR PACKAGING CORNMEAL

Marketing Research Report No. 970

JAN 1973  
SC 9

Agricultural Research Service  
UNITED STATES DEPARTMENT OF AGRICULTURE



## Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

## ACKNOWLEDGMENT

The authors wish to acknowledge the cooperation of John B. Canady, St. Regis Paper Co., and William H. Schoenherr, Lauhoff Grain Co. U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service, and Agricultural Research Service personnel were advisers for this study.

## CONTENTS

|                                                                    | Page |
|--------------------------------------------------------------------|------|
| Summary.....                                                       | 1    |
| Introduction.....                                                  | 1    |
| Experimental materials and methods.....                            | 2    |
| Moisture content.....                                              | 2    |
| Bag types.....                                                     | 2    |
| Storage conditions.....                                            | 2    |
| Sampling.....                                                      | 3    |
| Procedure and results.....                                         | 3    |
| Discussion.....                                                    | 4    |
| Moisture content of cornmeal stored in paper and cotton bags.....  | 4    |
| Moisture content of cornmeal stored in polyethylene-film bags..... | 4    |
| Fat acidity value.....                                             | 5    |
| Fat content of cornmeal stored in paper and cotton bags.....       | 6    |
| Fat content of cornmeal stored in polyethylene-film bags.....      | 6    |
| Conclusions.....                                                   | 7    |

Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

# EVALUATION OF PAPER, COTTON, AND POLYETHYLENE-FILM BAGS FOR PACKAGING CORNMEAL

By ROBERT M. JOHNSON,<sup>1</sup> *research chemist, Northeastern Region, Beltsville, Md.*; WALTER T. GREENWAY, *research chemist, North Central Region, Manhattan, Kans.*; and TYLER F. HARTSING, *grain technologist (retired), Agricultural Research Service, United States Department of Agriculture*

## SUMMARY

The relative effectiveness of paper, cotton, and polyethylene-film bags was compared for storing degermed cornmeal. Samples were stored in 3- and 50-pound bags for 24 weeks at Pensacola, Fla., under control, ambient, and high humidity conditions.

Moisture content of all samples was measured to determine its effect on storage. Moisture content indicated to some extent the conditions of storage, but moisture content is not considered a quality indicator.

The loss in quality of the cornmeal was determined by testing for fat acidity value and fat content and by performing olfactory and taste panel tests on corn muffins baked from the cornmeal. Fat acidity values fluctuated greatly. Moreover, because of lack of fat, some samples could not be properly tested for fat acidity. Therefore, fat content was used as the measure by which to judge

the quality of degermed cornmeal. Fat contents below a value of 1.0 percent indicated unacceptable cornmeal, between 1.0 and 1.15 indicated only fair-quality cornmeal, and above 1.15 indicated acceptable cornmeal.

Cornmeal in polyethylene-film bags was more resistant to both loss and gain in moisture than cornmeal in paper and cotton bags. However, under control storage conditions (73° F. and 50-percent relative humidity), paper, cotton, and polyethylene-film bags all were effective. Initial moisture content of cornmeal was not critical under these control storage conditions.

The paper and cotton bags were ineffective under ambient and high humidity storage conditions. The polyethylene-film bags were superior to the paper and cotton bags and protected cornmeal effectively from the time of packaging to end use under all but the most severe storage conditions.

## INTRODUCTION

The purpose of this 24-week storage study was to observe and measure changes in the quality of degermed cornmeal stored in paper, cotton, and polyethylene-film bags under control, ambient, and high humidity conditions. The study was designed to answer the following questions:

(1) How do polyethylene-film bags compare

with paper and cotton bags for preserving the quality of cornmeal?

- (2) How well do the fat acidity values and oil content predict deterioration in stored cornmeal?
- (3) What role does moisture play in the deterioration of cornmeal?
- (4) What criteria can be used to define quality in cornmeal?

<sup>1</sup> Presently, agriculturist, Northeastern Region, Agriculture Research Service, Beltsville, Md.

## EXPERIMENTAL MATERIALS AND METHODS

Regular-grind, degermed cornmeal was shipped from the Lauhoff Grain Company, Danville, Ill., to the St. Regis Paper Company, Pensacola, Fla. Upon arrival, the bulk cornmeal was immediately tempered to four moisture levels and packed into a total of four hundred 3-pound paper and cotton bags and 3- and 50-pound polyethylene-film bags. The samples prepared for the study were then randomly placed under three storage conditions at Pensacola after testing for moisture content, fat acidity, and fat content. Samples were sent to Danville and to Beltsville and tested for moisture content and fat acidity value after storage for 1, 2, 4, 6, 8, 12, and 24 weeks. Fat content was determined and corn muffins were baked and evaluated after storage for 1, 4, 8, 12, and 24 weeks at Beltsville. Corn muffins were also sent by air-mail to Pensacola for a taste panel evaluation.

### Moisture content

Four lots of the sample were tempered to moisture contents of approximately 11, 13, 14, and 15 percent to determine the effect of moisture content on cornmeal storage at Pensacola. Water was added very slowly to the cornmeal in a 30-gallon drum (figs. 1 and 2). The drum, fitted with baffles,



PN-2662

FIGURE 1.—Thirty-gallon drums with three 3-inch baffles used to insure thorough mixing of cornmeal and water.



PN-2663

FIGURE 2.—Adding water to cornmeal to achieve desired moisture content.

was rotated 20 revolutions in both directions to insure thorough mixing (fig. 3). After the mixture had been equilibrated overnight, several samples were drawn from each drum for analysis. Average original moisture contents were 11.0, 12.4, 13.4, and 15.0 percent.

### Bag types

The characteristics of the four types of bags in the study are described in table 1 and shown in figures 4 and 5.

### Storage conditions

- (1) 73° F., 50-percent relative humidity (control).
- (2) Under cover, outdoors (ambient).
- (3) 100° F., 90-percent relative humidity (high humidity storage cabinet).

Figure 6 shows the control storage cabinet, figure 7 shows the outdoors storage structures for

ambient conditions, and figure 8 shows the high humidity storage cabinet.

### Sampling

Bags of cornmeal were randomly placed in storage on the basis of moisture content and bag type. For each sampling period one 3-pound paper bag, one 3-pound cotton bag, and one 3-pound polyethylene-film bag for each treatment were airmailed to Danville and one of each to Beltsville

for analysis. One of each type bag was also kept at Pensacola for analysis. Samples were drawn from the top, center, and bottom of each 50-pound bag, with special effort to draw samples from the same area in each bag at successive samplings. One of each composite was sent to Danville and one to Beltsville, and one was kept at Pensacola for analysis. The contents of each bag was well mixed at the three laboratories and the entire sample was used for analysis.

## PROCEDURE AND RESULTS

Moisture content was determined on 2- to 5-gram samples of cornmeal by the American Association of Cereal Chemists' (AACC) air-oven method 44-15. Fat acidity value was determined on 20-gram samples by the AACC rapid method

02-03. Fat content was determined on 10-gram samples by the AACC method 30-20.<sup>2</sup>

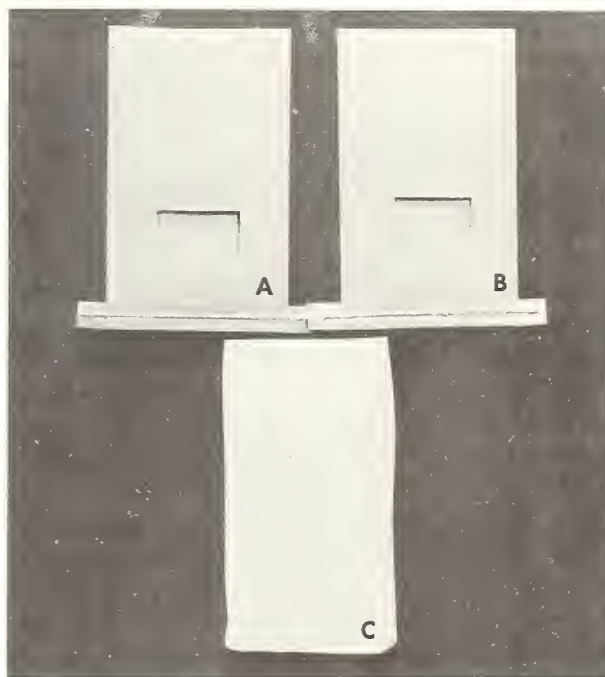
Average values from all laboratories for moisture content, fat acidity value, and fat content are shown for samples stored at control (table 2), ambient (table 3), and high humidity (table 4) conditions.

<sup>2</sup> AMERICAN ASSOCIATION OF CEREAL CHEMISTS. AACC APPROVED METHODS. (Formerly, Cereal Laboratory Methods, ed. 7.) The Association, St. Paul., Minn. 1962.



PN-2664

FIGURE 3.—Cornmeal and water mixed by tumbling in 30-gallon drum with baffles.



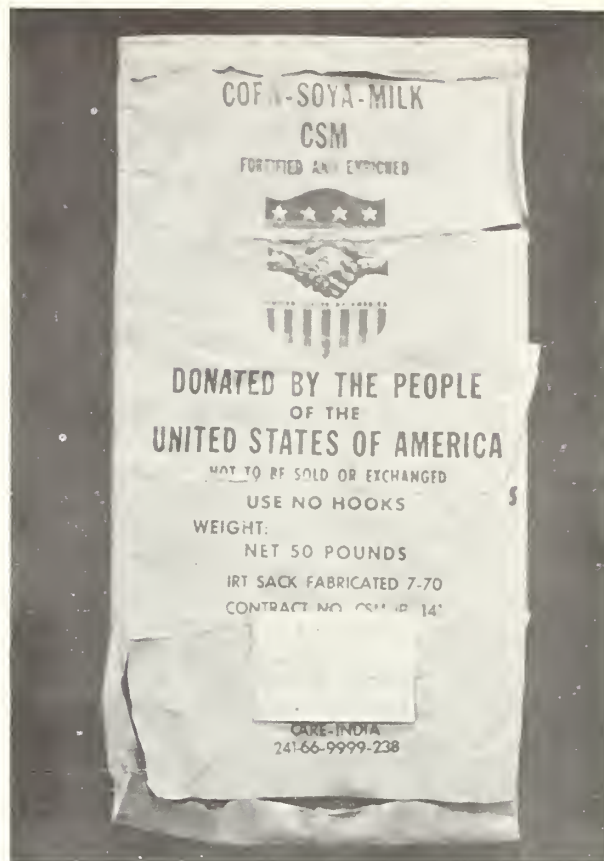
PN-2665

FIGURE 4.—A, 3-pound polyethylene-film; B, paper; and C, cotton bags used in study. Inner ply of polyethylene-film bag was heat sealed, both top and bottom.

The quality of the cornmeal after storage for 4 and 8 weeks is shown in table 5. Because fat acidity values fluctuated greatly and moisture content is not a true quality indicator, we decided to use fat content as the factor to judge the quality of degermed cornmeal. Percent fat contents below a value of 1.0 indicated unacceptable cornmeal, between 1.0 and 1.15 indicated only fair-quality cornmeal, and above 1.15 indicated acceptable cornmeal. This is also the basis of the ratings given in tables 5, 6, and 7.

Most samples stored at moisture contents of 12.4 and 13.4 percent in paper and cotton bags were not analyzed because we believed that valid conclusion could be obtained by observing the trend at the high and low moisture contents. However, most samples stored at all moisture contents in polyethylene-film bags were analyzed because this material was critically evaluated for its use in retaining the quality of the product in storage.

Odor and taste of corn muffins were evaluated by five-man panels at Beltsville and at Pensacola. The term "mustiness" was used to describe a characteristic odor and taste attributable to the action of molds. Mustiness seemed to be influenced by the moisture content of the cornmeal more than by the type container, storage condition, or time of storage. Mustiness in corn muffins, determined by the percentage of judges who described the baked product as musty, was plotted against the moisture content of the cornmeal and is shown in figure 9.



PN-2666

FIGURE 5.—Full-size, 50-pound polyethylene-film bag used in study. Inner ply was heat sealed, both top and bottom.

## DISCUSSION

### Moisture content of cornmeal stored in paper and cotton bags

As might be expected, the moisture content in samples of cornmeal low in original moisture content (11 to 12 percent) increased only slightly in paper and cotton bags when the cornmeal was stored under control and ambient conditions. However, the moisture content in samples of cornmeal high in original moisture content (15 percent) decreased significantly when the cornmeal was stored under these conditions. Therefore, imminent danger of deterioration of cornmeal high in original moisture content might be reduced by subsequent storing under control (table 2) or ambient (table 3) conditions.

Figure 10 shows visible mold contaminations on a paper bag after storage for 1 week under high humidity conditions. This contamination was due to the increase in moisture content, which, in turn, allowed the growth of micro-organisms that caused objectionable odor and taste in the baked corn muffins. Figure 11 shows the same condition on a cotton bag.

### Moisture content of cornmeal stored in polyethylene-film bags

Moisture content of cornmeal stored for 24 weeks in polyethylene-film bags under all conditions increased only about 1 percent. Cornmeal in polyethylene-film bags was free of visible mold

TABLE 1.—*Types of bags used for storing degermed cornmeal*

| Bag type                        | Size            | Bag construction                                                                                                                      |
|---------------------------------|-----------------|---------------------------------------------------------------------------------------------------------------------------------------|
|                                 | <i>Inches</i>   |                                                                                                                                       |
| 3-pound paper-----              | 7 ½ by 12 ¼     | 4 inner ply—50-weight basis, 1 outer ply—60-weight basis, natural kraft paper, wet strength, insect resistant, flat tube pouch, sewn. |
| 3-pound cotton-----             | 7 ½ by 12 ¼     | Cotton, sewn.                                                                                                                         |
| 3-pound polyethylene film-----  | 7 ½ by 12 ¼     | Same as 3-pound paper bag above, plus 1 innermost ply, 3.0-mil polyethylene film, heat sealed, both top and bottom.                   |
| 50-pound polyethylene film----- | 16 by 4 by 32 ½ | Same as 3-pound polyethylene-film bag above, plus stripe laminated, pasted open mouth.                                                |

contamination after storage for 8 weeks under high humidity conditions (fig. 12). However, a musty odor was apparent in the cornmeal when the bags were opened for analysis. Table 6 summarizes the effect of storage conditions and time of storage upon the quality of cornmeal stored in polyethylene-film bags.

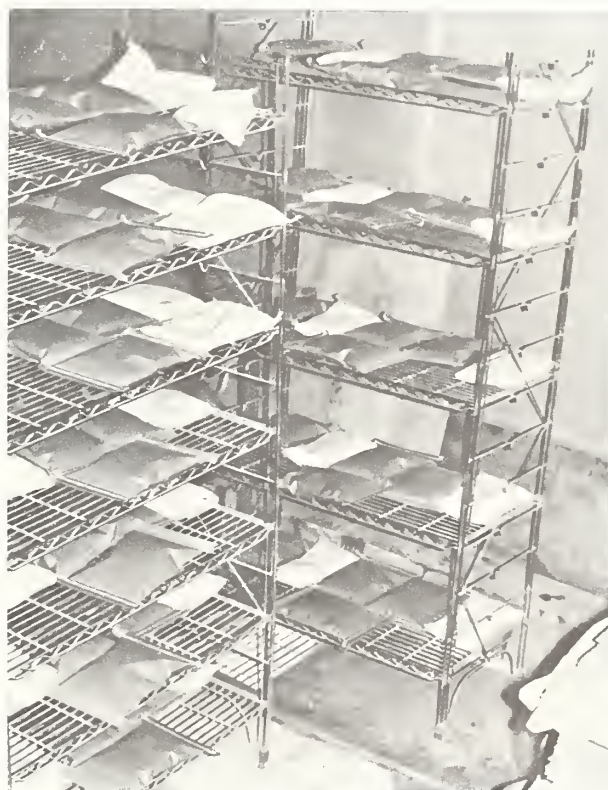
The polyethylene-film bag was far superior to the paper and cotton bags. Although paper, cotton, and polyethylene-film bags were effective under control conditions, only the polyethylene-film bags were effective under ambient and high humidity storage conditions for 12 weeks (tables 5, 6, and 7). These data emphasize the need to keep the cornmeal in low-humidity environments. Moisture in the cornmeal can be controlled by storing the cornmeal under control conditions, where all three types of bags maintained quality effectively. Quality in low-moisture cornmeal can also be maintained by storing the cornmeal in polyethylene-film bags that are relatively impermeable to moisture.

A disadvantage of using polyethylene-film bags for packaging cornmeal at high moisture content (about 15 percent) is that a musty odor develops and carries over into the baked product. Moisture cannot escape through the polyethylene-film even when the bags are stored in a dry atmosphere (table 2).

### Fat acidity value

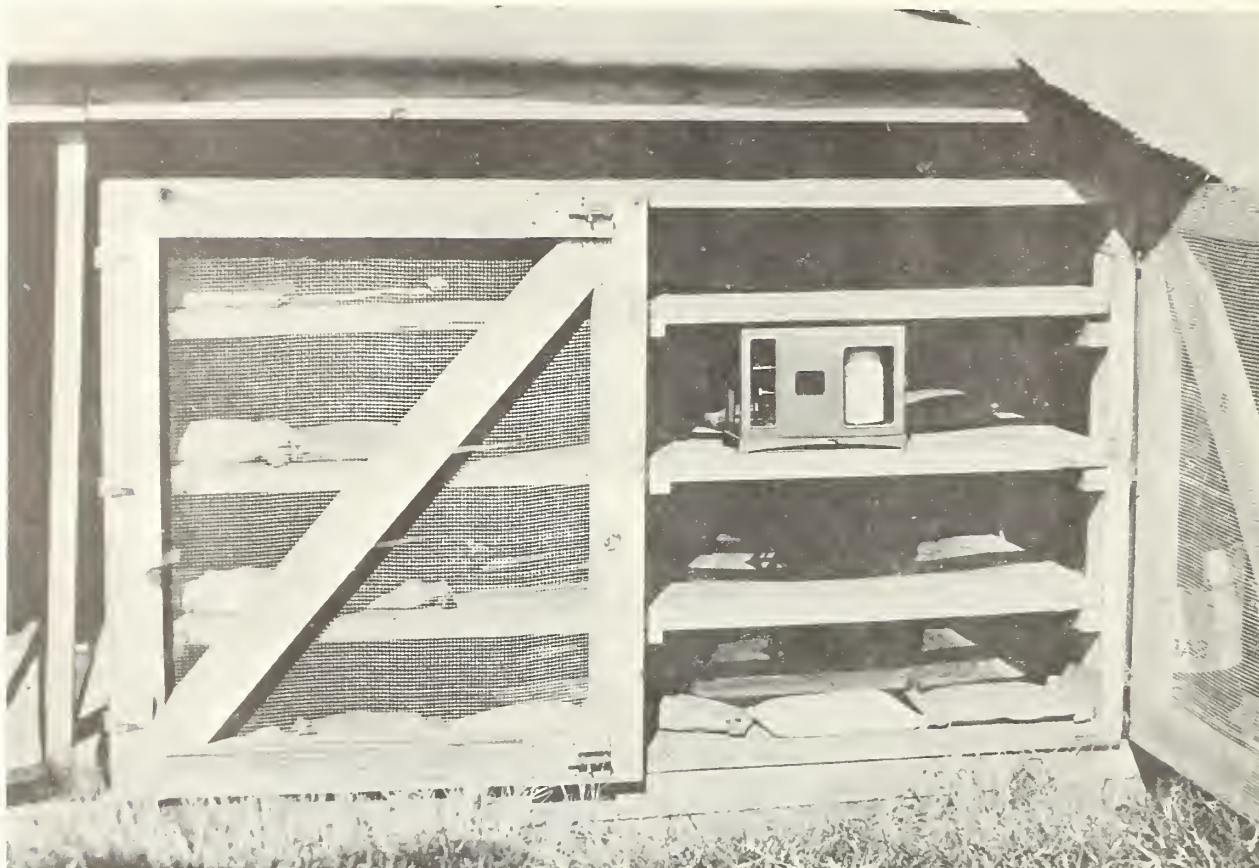
When cornmeal was stored under control conditions, fat acidity values increased as moisture content and time of storage increased, regardless

of the type of bag used (table 2). When cornmeal was stored in paper and cotton bags under ambient and high humidity conditions, fat acidity values increased for about 1 to 4 weeks but then decreased significantly because the fat content also decreased. The decrease in fat content and fat



PN-2667

FIGURE 6.—Samples of cornmeal stored in control cabinet (73° F., 50-percent relative humidity).



PN-2668

FIGURE 7.—Samples of cornmeal stored under cover, outdoors (ambient conditions).

acidity value to near zero at the end of 24 weeks of storage is believed to be due to binding of the fat to the cornmeal. This explanation was proved by the fact that the fat was released from the cornmeal by acid hydrolysis when another solvent was used.

When cornmeal was stored in polyethylene-film bags under all conditions, the fat acidity values increased as moisture content and time of storage increased.

#### **Fat content of cornmeal stored in paper and cotton bags**

Cornmeal in paper and cotton bags stored under high humidity conditions showed evidence of deterioration after 1 week by a decrease of about one-third of the original fat content (table 8). However, cornmeal in similar bags stored under

ambient conditions showed no evidence of deterioration until after 4 weeks.

#### **Fat content of cornmeal stored in polyethylene-film bags**

Loss in fat content was the best single indicator for predicting deterioration of degermed cornmeal under high humidity conditions, regardless of the type of bag used (table 8). Even in the cornmeal in polyethylene-film bags stored under high humidity conditions, the fat content decreased significantly as time of storage increased. Change in fat content appears to be related to change in moisture level (table 7).

Results from the analysis of cornmeal stored in 50-pound polyethylene-film bags did not differ significantly from the results of cornmeal stored in 3-pound polyethylene-film bags.



PN-2669

FIGURE 8.—Samples of cornmeal stored in high humidity storage cabinet (100° F., 90-percent relative humidity).

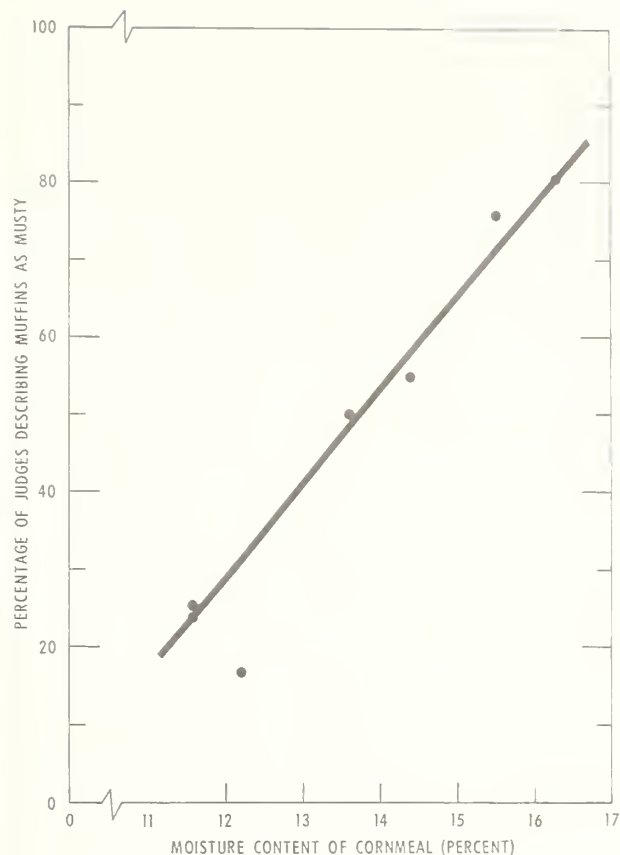


FIGURE 9.—Mustiness in cornmeal muffins compared with moisture content of cornmeal.

## CONCLUSIONS

During the 24-week storage period, fat acidity values for cornmeal stored in paper and cotton bags under control conditions increased as time of storage increased. However, the fat acidity value for cornmeal stored in paper and cotton bags under high humidity conditions decreased significantly after storage for 2 weeks and after 6 weeks under ambient conditions, indicating that deterioration had taken place. Fat acidity values for cornmeal stored in polyethylene-film bags under all conditions increased as moisture content and time of storage increased.

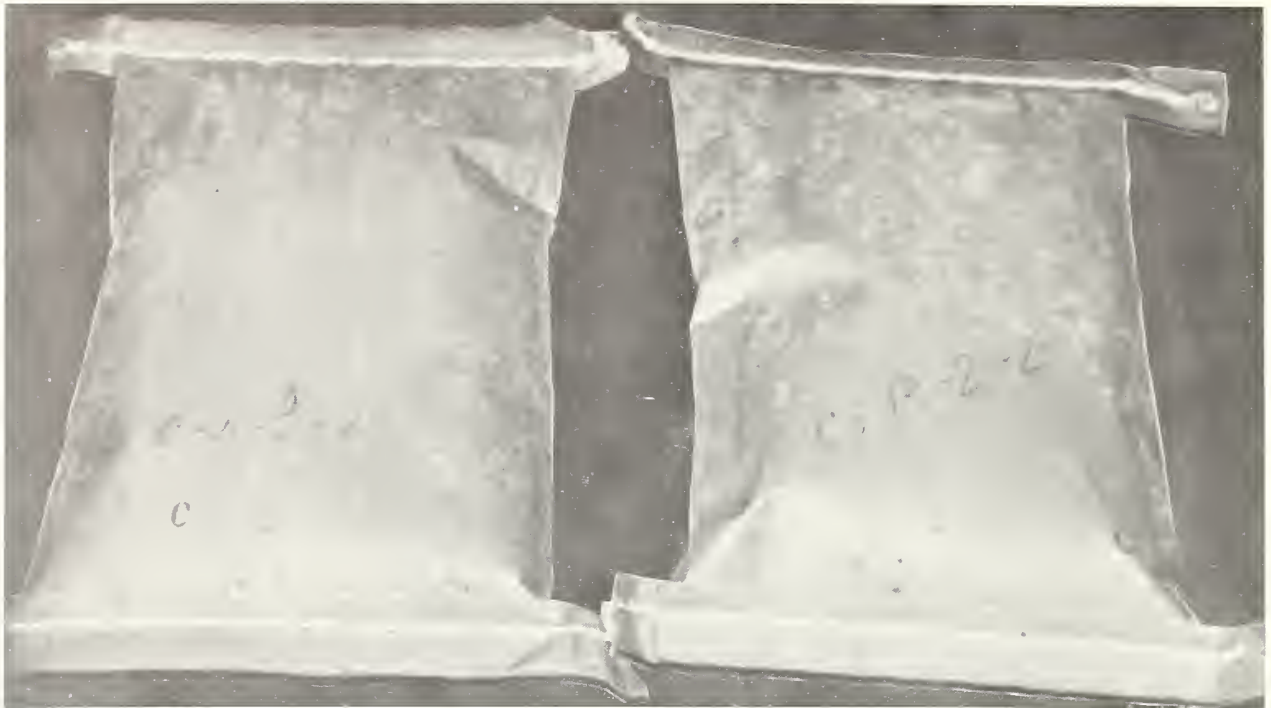
When cornmeal with low original moisture content was stored in paper and cotton bags under ambient conditions for 8 weeks, fat content decreased to less than one-half of the original fat

content. When cornmeal was stored in polyethylene-film bags under the same conditions, fat content did not change significantly.

Deterioration in cornmeal was indicated by an objectionable odor and taste of the baked product, along with an extremely low oil content and negligible fat acidity value.

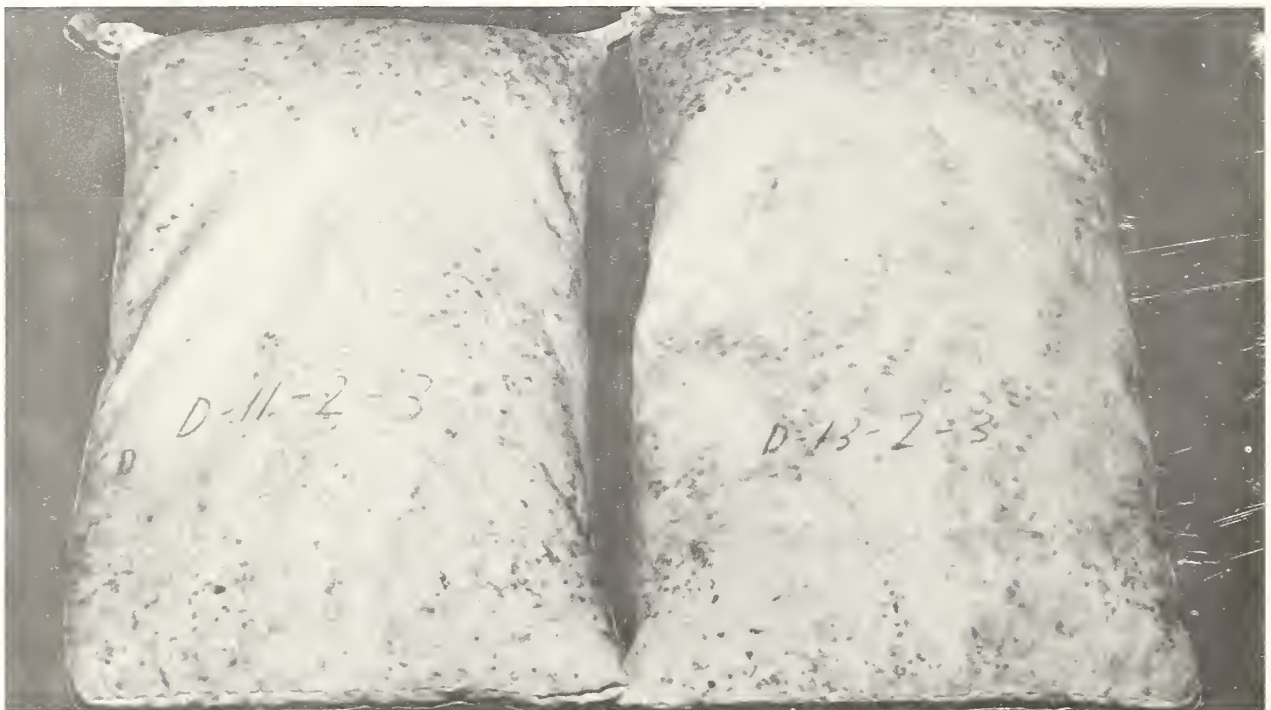
The primary advantage of polyethylene-film over paper and cotton is that the film barrier permits better retention of cornmeal quality from the time of packaging to final end use.

Because mustiness in corn muffins seems to be related to moisture content of cornmeal, regardless of the type of bag used, cornmeal should be packaged at the lowest possible moisture consistent with recognized milling practices.



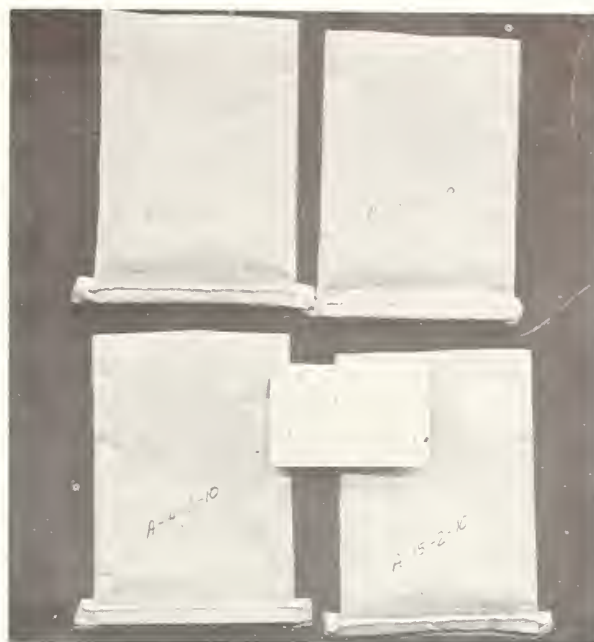
PN-2670

FIGURE 10.—Paper bags showing mold contamination after storage for 1 week at 100° F. and 90-percent relative humidity.



PN-2671

FIGURE 11.—Cotton bags showing mold contamination after storage for 1 week at 100° F. and 90-percent relative humidity.



PN-2672

FIGURE 12.—Paper bags with polyethylene-film inserts after storage for 8 weeks at 100° F. and 90-percent relative humidity.

TABLE 2.—Moisture content, fat acidity value, and fat content of cornmeal stored at 73° F. and 50-percent relative humidity (control conditions)<sup>1</sup>

| Type of container and time of storage | Actual moisture content when original moisture content (percent) of sample was— |       |       |      | Fat acidity value when original moisture content (percent) of sample was— |      |      |      | Fat content when original moisture content (percent) of sample was— |       |       |       |
|---------------------------------------|---------------------------------------------------------------------------------|-------|-------|------|---------------------------------------------------------------------------|------|------|------|---------------------------------------------------------------------|-------|-------|-------|
|                                       | 11.0                                                                            | 12.4  | 13.4  | 15.0 | 11.0                                                                      | 12.4 | 13.4 | 15.0 | 11.0                                                                | 12.4  | 13.4  | 15.0  |
|                                       | ----- Percent -----                                                             |       |       |      |                                                                           |      |      |      | ----- Percent -----                                                 |       |       |       |
| Paper:                                |                                                                                 |       |       |      |                                                                           |      |      |      |                                                                     |       |       |       |
| 0 week.....                           | 11.0                                                                            | 12.4  | 13.4  | 15.0 | 35                                                                        | 35   | 37   | 57   | 1.54                                                                | 1.54  | 1.54  | 1.47  |
| 1 week.....                           | 11.7                                                                            | ----- | ----- | 12.0 | 43                                                                        | --   | --   | 49   | 1.47                                                                | ----- | ----- | 1.43  |
| Cotton:                               |                                                                                 |       |       |      |                                                                           |      |      |      |                                                                     |       |       |       |
| 0 week.....                           | 11.0                                                                            | 12.4  | 13.4  | 15.0 | 35                                                                        | 35   | 37   | 57   | 1.54                                                                | 1.54  | 1.54  | 1.49  |
| 1 week.....                           | 11.9                                                                            | ----- | ----- | 12.1 | 46                                                                        | --   | --   | 48   | 1.51                                                                | ----- | ----- | 1.45  |
| 2 weeks.....                          | 11.7                                                                            | ----- | ----- | 11.8 | 47                                                                        | --   | --   | 54   | -----                                                               | ----- | ----- | ----- |
| 4 weeks.....                          | 11.5                                                                            | ----- | ----- | 11.6 | 70                                                                        | --   | --   | 80   | 1.60                                                                | ----- | ----- | 1.57  |
| 6 weeks.....                          | 11.2                                                                            | ----- | ----- | 11.5 | 64                                                                        | --   | --   | 74   | -----                                                               | ----- | ----- | ----- |
| 8 weeks.....                          | 12.4                                                                            | ----- | ----- | 12.3 | 72                                                                        | --   | --   | 90   | 1.58                                                                | ----- | ----- | 1.55  |
| Polyethylene film:                    |                                                                                 |       |       |      |                                                                           |      |      |      |                                                                     |       |       |       |
| 0 week.....                           | 11.0                                                                            | 12.4  | 13.4  | 15.0 | 35                                                                        | 35   | 37   | 57   | 1.47                                                                | 1.54  | 1.54  | 1.49  |
| 2 weeks.....                          | 11.6                                                                            | 13.3  | 14.4  | 15.6 | 47                                                                        | 57   | 65   | 95   | -----                                                               | ----- | ----- | ----- |
| 4 weeks.....                          | 11.5                                                                            | 13.3  | 14.2  | 15.5 | 62                                                                        | 82   | 98   | 181  | 1.57                                                                | 1.52  | 1.54  | 1.41  |
| 6 weeks.....                          | 11.5                                                                            | 13.3  | 14.1  | 15.3 | 64                                                                        | 78   | 101  | 173  | -----                                                               | ----- | ----- | ----- |
| 8 weeks.....                          | 11.3                                                                            | 13.2  | 14.1  | 15.2 | 73                                                                        | 95   | 112  | 177  | 1.58                                                                | 1.49  | 1.48  | 1.47  |

<sup>1</sup> Average values of 3 laboratories.

TABLE 3.—*Moisture content, fat acidity value, and fat content of cornmeal stored at ambient conditions*<sup>1</sup>

| Type of container and<br>time of storage | Actual moisture content when<br>original moisture content<br>(percent) of sample was— |      |      |      | Fat acidity value when<br>original moisture content<br>(percent) of sample was— |      |      |      | Fat content when original<br>moisture content (percent)<br>of sample was— |      |      |      |
|------------------------------------------|---------------------------------------------------------------------------------------|------|------|------|---------------------------------------------------------------------------------|------|------|------|---------------------------------------------------------------------------|------|------|------|
|                                          | 11.0                                                                                  | 12.4 | 13.4 | 15.0 | 11.0                                                                            | 12.4 | 13.4 | 15.0 | 11.0                                                                      | 12.4 | 13.4 | 15.0 |
|                                          | ----- Percent -----                                                                   |      |      |      |                                                                                 |      |      |      | ----- Percent -----                                                       |      |      |      |
| Paper:                                   |                                                                                       |      |      |      |                                                                                 |      |      |      |                                                                           |      |      |      |
| 0 week.....                              | 11.0                                                                                  | 12.4 | 13.4 | 15.0 | 35                                                                              | 35   | 37   | 57   | 1.54                                                                      | 1.54 | 1.47 | 1.49 |
| 2 weeks.....                             | 14.3                                                                                  | ---- | ---- | 15.3 | 74                                                                              | --   | --   | 132  | ----                                                                      | ---- | ---- | ---- |
| 4 weeks.....                             | 14.7                                                                                  | ---- | ---- | 15.1 | 168                                                                             | --   | --   | 140  | 1.28                                                                      | ---- | ---- | .94  |
| 6 weeks.....                             | 14.6                                                                                  | 15.1 | ---- | ---- | 91                                                                              | --   | --   | 112  | ----                                                                      | ---- | ---- | ---- |
| 8 weeks.....                             | 14.7                                                                                  | 14.3 | ---- | --   | 93                                                                              | --   | --   | 114  | .64                                                                       | ---- | ---- | .66  |
| Cotton:                                  |                                                                                       |      |      |      |                                                                                 |      |      |      |                                                                           |      |      |      |
| 0 week.....                              | 11.0                                                                                  | 12.4 | 13.4 | 15.0 | 35                                                                              | 35   | 37   | 57   | 1.49                                                                      | 1.54 | 1.47 | 1.47 |
| 2 weeks.....                             | 14.9                                                                                  | ---- | ---- | 15.0 | 75                                                                              | --   | --   | 132  | ----                                                                      | ---- | ---- | ---- |
| 4 weeks.....                             | 13.8                                                                                  | ---- | ---- | 14.2 | 164                                                                             | --   | --   | 142  | 1.14                                                                      | ---- | ---- | 1.05 |
| 6 weeks.....                             | 14.6                                                                                  | ---- | ---- | 14.6 | 90                                                                              | --   | --   | 108  | ----                                                                      | ---- | ---- | ---- |
| 8 weeks.....                             | 13.4                                                                                  | ---- | ---- | 14.0 | 98                                                                              | --   | --   | 113  | .66                                                                       | ---- | ---- | .73  |
| 12 weeks.....                            | 14.4                                                                                  | 14.4 | ---- | ---- | 73                                                                              | 72   | --   | --   | .66                                                                       | ---- | ---- | .59  |
| 24 weeks.....                            | 14.8                                                                                  | 14.9 | ---- | ---- | 78                                                                              | 79   | --   | --   | .49                                                                       | ---- | ---- | .52  |
| Polyethylene film:                       |                                                                                       |      |      |      |                                                                                 |      |      |      |                                                                           |      |      |      |
| 0 week.....                              | 11.0                                                                                  | 12.4 | 13.4 | 15.0 | 35                                                                              | 35   | 37   | 57   | 1.49                                                                      | 1.54 | 1.47 | 1.54 |
| 2 weeks.....                             | 11.7                                                                                  | 13.5 | 14.5 | 15.6 | 58                                                                              | 66   | 70   | 128  | ----                                                                      | ---- | ---- | ---- |
| 4 weeks.....                             | 11.8                                                                                  | 13.3 | 14.0 | 15.6 | 77                                                                              | 85   | 111  | 207  | 1.58                                                                      | 1.52 | 1.54 | 1.34 |
| 6 weeks.....                             | 12.0                                                                                  | 13.5 | 14.7 | 15.8 | 70                                                                              | 86   | 141  | 184  | ----                                                                      | ---- | ---- | ---- |
| 8 weeks.....                             | 11.9                                                                                  | 13.6 | 14.8 | 15.9 | 79                                                                              | 103  | 133  | 192  | 1.56                                                                      | 1.47 | 1.16 | 1.26 |
| 12 weeks.....                            | 11.9                                                                                  | 13.5 | ---- | ---- | 81                                                                              | 107  | ---- | ---- | 1.48                                                                      | ---- | ---- | 1.45 |
| 24 weeks.....                            | 12.4                                                                                  | 14.0 | ---- | ---- | 107                                                                             | 144  | ---- | ---- | 1.53                                                                      | ---- | ---- | 1.52 |

<sup>1</sup> Average values of 3 laboratories.

TABLE 4.—*Moisture content, fat acidity value, and fat content of cornmeal stored at 100° F. and 90-percent relative humidity (high humidity conditions)*<sup>1</sup>

| Type of container<br>and time of<br>storage | Actual moisture content<br>when original moisture<br>content (percent) of sample was— |       |       |       | Fat acidity value when<br>original moisture content<br>(percent) of sample was— |      |      |      | Fat content when original<br>moisture content (percent)<br>of sample was— |       |       |       |
|---------------------------------------------|---------------------------------------------------------------------------------------|-------|-------|-------|---------------------------------------------------------------------------------|------|------|------|---------------------------------------------------------------------------|-------|-------|-------|
|                                             | 11.0                                                                                  | 12.4  | 13.4  | 15.0  | 11.0                                                                            | 12.4 | 13.4 | 15.0 | 11.0                                                                      | 12.4  | 13.4  | 15.0  |
|                                             | ----- <i>Percent</i> -----                                                            |       |       |       | ----- <i>Percent</i> -----                                                      |      |      |      |                                                                           |       |       |       |
| Paper:                                      |                                                                                       |       |       |       |                                                                                 |      |      |      |                                                                           |       |       |       |
| 0 week-----                                 | 11.0                                                                                  | 12.4  | 13.4  | 15.0  | 35                                                                              | 35   | 37   | 57   | 1.54                                                                      | 1.54  | 1.47  | 1.47  |
| 1 week-----                                 | 15.1                                                                                  | ----- | ----- | 15.4  | 158                                                                             | ---  | ---  | 50   | 1.06                                                                      | ----- | ----- | .87   |
| 2 weeks-----                                | 15.5                                                                                  | ----- | ----- | 16.0  | 51                                                                              | ---  | ---  | 53   | -----                                                                     | ----- | ----- | ----- |
| 4 weeks-----                                | 15.8                                                                                  | ----- | ----- | 16.3  | 19                                                                              | ---  | ---  | 21   | .27                                                                       | ----- | ----- | .62   |
| 6 weeks-----                                | 16.2                                                                                  | 16.4  | ----- | ----- | 18                                                                              | ---  | ---  | 17   | -----                                                                     | ----- | ----- | ----- |
| 8 weeks-----                                | 16.9                                                                                  | 16.6  | ----- | ----- | 9                                                                               | ---  | ---  | 8    | .11                                                                       | ----- | ----- | .09   |
| Cotton:                                     |                                                                                       |       |       |       |                                                                                 |      |      |      |                                                                           |       |       |       |
| 0 week-----                                 | 11.0                                                                                  | 12.4  | 13.4  | 15.0  | 35                                                                              | 35   | 37   | 57   | 1.49                                                                      | 1.54  | 1.47  | 1.54  |
| 1 week-----                                 | 15.5                                                                                  | ----- | ----- | 15.3  | 155                                                                             | ---  | ---  | 56   | 1.00                                                                      | ----- | ----- | .97   |
| 2 weeks-----                                | 15.9                                                                                  | ----- | ----- | 16.0  | 75                                                                              | ---  | ---  | 51   | -----                                                                     | ----- | ----- | ----- |
| 4 weeks-----                                | 15.5                                                                                  | ----- | ----- | 15.1  | 36                                                                              | ---  | ---  | 23   | .33                                                                       | ----- | ----- | .26   |
| 6 weeks-----                                | 15.8                                                                                  | ----- | ----- | 15.6  | 16                                                                              | ---  | ---  | 16   | -----                                                                     | ----- | ----- | ----- |
| 8 weeks-----                                | 16.4                                                                                  | ----- | ----- | 16.2  | 11                                                                              | ---  | ---  | 10   | .12                                                                       | ----- | ----- | .09   |
| 12 weeks-----                               | 17.2                                                                                  | 17.3  | ----- | ----- | 7                                                                               | 6    | ---  | ---  | .07                                                                       | ----- | ----- | .10   |
| 24 weeks-----                               | 17.1                                                                                  | 16.8  | ----- | ----- | 4                                                                               | 4    | ---  | ---  | .05                                                                       | ----- | ----- | .07   |
| Polyethylene film:                          |                                                                                       |       |       |       |                                                                                 |      |      |      |                                                                           |       |       |       |
| 0 week-----                                 | 11.0                                                                                  | 12.4  | 13.4  | 15.0  | 35                                                                              | 35   | 37   | 57   | 1.49                                                                      | 1.54  | 1.47  | 1.54  |
| 2 weeks-----                                | 11.7                                                                                  | 13.5  | 14.5  | 15.7  | 64                                                                              | 81   | 108  | 192  | -----                                                                     | ----- | ----- | ----- |
| 4 weeks-----                                | 12.1                                                                                  | 13.9  | 14.6  | 15.9  | 91                                                                              | 119  | 213  | 234  | 1.73                                                                      | 1.51  | 1.29  | 1.30  |
| 6 weeks-----                                | 12.3                                                                                  | 13.7  | 14.3  | 15.7  | 94                                                                              | 121  | 196  | 193  | -----                                                                     | ----- | ----- | ----- |
| 8 weeks-----                                | 12.5                                                                                  | 14.3  | 15.1  | 16.3  | 115                                                                             | 141  | 195  | 187  | 1.57                                                                      | 1.34  | 1.19  | 1.18  |
| 12 weeks-----                               | 12.9                                                                                  | 14.4  | ----- | ----- | 125                                                                             | 136  | ---  | ---  | 1.36                                                                      | ----- | ----- | 1.22  |
| 24 weeks-----                               | 12.1                                                                                  | 12.9  | ----- | ----- | 195                                                                             | 161  | ---  | ---  | 1.22                                                                      | ----- | ----- | .95   |

<sup>1</sup> Average values of 3 laboratories.

TABLE 5.—*Quality of cornmeal after storage for 4 and 8 weeks*

| Original moisture content and time of storage |              | Storage condition  | Quality of cornmeal stored in— |                   |                   |
|-----------------------------------------------|--------------|--------------------|--------------------------------|-------------------|-------------------|
|                                               |              |                    | Paper bags                     | Cotton bags       | Polyethylene film |
| <i>Percent</i>                                | <i>Weeks</i> |                    |                                |                   |                   |
| 11                                            | 4            | Control.....       | ( <sup>1</sup> )               | Acceptable.....   | Acceptable.       |
| 11                                            | 4            | Ambient.....       | Acceptable.....                | Fair.....         | Do.               |
| 11                                            | 4            | High humidity..... | Unacceptable.....              | Unacceptable..... | Do.               |
| 15                                            | 4            | Control.....       | ( <sup>1</sup> )               | Acceptable.....   | Do.               |
| 15                                            | 4            | Ambient.....       | Unacceptable.....              | Fair.....         | Do.               |
| 15                                            | 4            | High humidity..... | do.....                        | Unacceptable..... | Do.               |
| 11                                            | 8            | Control.....       | ( <sup>1</sup> )               | Acceptable.....   | Do.               |
| 11                                            | 8            | Ambient.....       | Unacceptable.....              | Unacceptable..... | Do.               |
| 11                                            | 8            | High humidity..... | do.....                        | do.....           | Do.               |
| 15                                            | 8            | Control.....       | ( <sup>1</sup> )               | Acceptable.....   | Do.               |
| 15                                            | 8            | Ambient.....       | Unacceptable.....              | Unacceptable..... | Do.               |
| 15                                            | 8            | High humidity..... | do.....                        | do.....           | Do.               |

<sup>1</sup> Item was not measured.TABLE 6.—*Effect of storage conditions and time of storage upon quality of cornmeal stored in polyethylene-film bags.*

| Original moisture content and storage conditions | Quality of cornmeal after storage for— |                |                |                  |                  |
|--------------------------------------------------|----------------------------------------|----------------|----------------|------------------|------------------|
|                                                  | 0 week                                 | 4 weeks        | 8 weeks        | 12 weeks         | 24 weeks         |
| 11 percent:                                      |                                        |                |                |                  |                  |
| Control.....                                     | Acceptable....                         | Acceptable.... | Acceptable.... | ( <sup>1</sup> ) | ( <sup>1</sup> ) |
| Ambient.....                                     | do.....                                | do.....        | do.....        | Acceptable....   | Acceptable.      |
| High humidity.....                               | do.....                                | do.....        | do.....        | do.....          | Do.              |
| 12.4 percent:                                    |                                        |                |                |                  |                  |
| Control.....                                     | do.....                                | do.....        | do.....        | ( <sup>1</sup> ) | ( <sup>1</sup> ) |
| Ambient.....                                     | do.....                                | do.....        | do.....        | ( <sup>1</sup> ) | ( <sup>1</sup> ) |
| High humidity.....                               | do.....                                | do.....        | do.....        | ( <sup>1</sup> ) | ( <sup>1</sup> ) |
| 13.4 percent:                                    |                                        |                |                |                  |                  |
| Control.....                                     | do.....                                | do.....        | do.....        | ( <sup>1</sup> ) | ( <sup>1</sup> ) |
| Ambient.....                                     | do.....                                | do.....        | do.....        | ( <sup>1</sup> ) | ( <sup>1</sup> ) |
| High humidity.....                               | do.....                                | do.....        | do.....        | ( <sup>1</sup> ) | ( <sup>1</sup> ) |
| 15 percent:                                      |                                        |                |                |                  |                  |
| Control.....                                     | do.....                                | do.....        | do.....        | ( <sup>1</sup> ) | ( <sup>1</sup> ) |
| Ambient.....                                     | do.....                                | do.....        | do.....        | Acceptable....   | Acceptable.      |
| High humidity.....                               | do.....                                | do.....        | do.....        | do.....          | Unacceptable.    |

<sup>1</sup> Item not measured.

TABLE 7.—*Changes in moisture content and fat content and quality of cornmeal containing 11 percent moisture stored under different conditions for 4 weeks.*

| Type container and storage condition | Change in—       |                  | Moisture content after storage for 4 weeks | Quality of cornmeal |
|--------------------------------------|------------------|------------------|--------------------------------------------|---------------------|
|                                      | Moisture content | Fat content      |                                            |                     |
| Paper bags:                          |                  |                  |                                            |                     |
| Control.....                         | ( <sup>1</sup> ) | ( <sup>1</sup> ) | ( <sup>1</sup> )                           | ( <sup>1</sup> )    |
| Ambient.....                         | +3.7             | −0.26            | 14.7                                       | Acceptable.         |
| High humidity.....                   | +4.8             | −1.27            | 15.8                                       | Unacceptable.       |
| Cotton bags:                         |                  |                  |                                            |                     |
| Control.....                         | +0.5             | +0.06            | 11.5                                       | Acceptable.         |
| Ambient.....                         | +2.8             | −0.35            | 13.8                                       | Fair.               |
| High humidity.....                   | +4.5             | −1.16            | 15.5                                       | Unacceptable.       |
| Polyethylene-film:                   |                  |                  |                                            |                     |
| Control.....                         | +0.5             | +0.03            | 11.5                                       | Acceptable.         |
| Ambient.....                         | +0.8             | +0.09            | 11.8                                       | Do.                 |
| High humidity.....                   | +1.1             | +0.24            | 12.1                                       | Do.                 |

<sup>1</sup> Item was not measured.

TABLE 8.—*Fat content of cornmeal stored in paper, cotton, and polyethylene-film bags*

| Storage condition and<br>time of storage | Fat content of cornmeal<br>stored in paper<br>bags when original moisture<br>content (percent) was— |                  | Fat content of cornmeal<br>stored in cotton<br>bags when original moisture<br>content (percent) was— |      | Fat content of cornmeal<br>stored in polyethylene-film<br>bags when original moisture<br>content (percent) was— |                  |
|------------------------------------------|-----------------------------------------------------------------------------------------------------|------------------|------------------------------------------------------------------------------------------------------|------|-----------------------------------------------------------------------------------------------------------------|------------------|
|                                          | 11                                                                                                  | 15               | 11                                                                                                   | 15   | 11                                                                                                              | 15               |
|                                          | ----- Percent -----                                                                                 |                  |                                                                                                      |      |                                                                                                                 |                  |
| Ambient:                                 |                                                                                                     |                  |                                                                                                      |      |                                                                                                                 |                  |
| 0 week.....                              | 1.54                                                                                                | 1.49             | 1.49                                                                                                 | 1.47 | 1.49                                                                                                            | 1.54             |
| 4 weeks.....                             | 1.28                                                                                                | 0.94             | 1.14                                                                                                 | 1.05 | 1.58                                                                                                            | 1.34             |
| 8 weeks.....                             | 0.64                                                                                                | 0.66             | 0.66                                                                                                 | 0.73 | 1.56                                                                                                            | 1.26             |
| 12 weeks.....                            | ( <sup>1</sup> )                                                                                    | ( <sup>1</sup> ) | 0.66                                                                                                 | 0.59 | 1.48                                                                                                            | 1.45             |
| 24 weeks.....                            | ( <sup>1</sup> )                                                                                    | ( <sup>1</sup> ) | 0.49                                                                                                 | 0.52 | 1.53                                                                                                            | 1.52             |
| High humidity:                           |                                                                                                     |                  |                                                                                                      |      |                                                                                                                 |                  |
| 0 week.....                              | 1.54                                                                                                | 1.47             | 1.49                                                                                                 | 1.54 | 1.49                                                                                                            | 1.54             |
| 1 week.....                              | 1.06                                                                                                | 0.87             | 1.00                                                                                                 | 0.97 | ( <sup>1</sup> )                                                                                                | ( <sup>1</sup> ) |
| 4 weeks.....                             | 0.27                                                                                                | 0.62             | 0.33                                                                                                 | 0.26 | 1.73                                                                                                            | 1.30             |
| 8 weeks.....                             | 0.11                                                                                                | 0.09             | 0.12                                                                                                 | 0.09 | 1.57                                                                                                            | 1.18             |
| 12 weeks.....                            | ( <sup>1</sup> )                                                                                    | ( <sup>1</sup> ) | 0.07                                                                                                 | 0.10 | 1.36                                                                                                            | 1.22             |
| 24 weeks.....                            | ( <sup>1</sup> )                                                                                    | ( <sup>1</sup> ) | 0.05                                                                                                 | 0.07 | 1.22                                                                                                            | 0.55             |

<sup>1</sup> Item was not measured.